HIV RISK IN PARTNERS OF MIGRANTS AND RESIDENTS IN RAKAI, UGANDA: AN OBSERVATIONAL COHORT STUDY

by
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Abstract

Background: Migration status has been linked to a higher burden of untreated HIV infection throughout sub-Saharan Africa. In Rakai District, Uganda, we have previously shown that migrants have an increased risk of HIV acquisition during the first two years following migration into a new community. However, little is known about these in-migrants' sexual partners. Here, we characterized in-migrants' sexual partner pool and examined their risk for pairing with an untreated HIV-positive individual.

Methods: From 1999 through 2016, we continuously surveyed 30 communities in Rakai District, Uganda as part of the Rakai Community Cohort Study (RCCS). In this open population-based cohort study, participants aged 15 to 49 reported on their four most recent sexual partners in the last year at each survey visit. We compared the self-reported characteristics of sexual partners of recent in-migrants (arrival < 2 years) and residents stratified by gender. Within a subset of linked cohabitating couples of known HIV serostatus, we also measured the prevalence of untreated HIV infection among partners comparing recent in-migrants to residents using log-binomial regression. Data were analyzed at each survey visit (12 surveys total) to assess calendar trends before and after the availability of antiretroviral therapy (ART).

Results: In total, 116,749 sexual partners were self-reported by 29,423 RCCS participants. Within both genders, we observed increased sexual risk behaviors in the partnerships of in-migrants compared to those of residents. Among 7,558 cohabitating couples of known HIV serostatus (21,140 couple-visits), migrants were significantly more likely to partner with other migrants. The prevalence of untreated HIV infection was significantly higher among cohabitating partners of HIV-negative in-migrants compared to residents irrespective of gender. HIV-negative in-migrant women and men were more likely to partner with untreated HIV-

positive individuals compared to residents before and after the availability of ART (Female PRR=1.55, 95% CI: 1.30-1.85; Male PRR=1.74, 95% CI: 1.40-2.17).

Conclusion: HIV-negative in-migrants are more likely than HIV-negative residents to partner with untreated HIV-positive individuals. These findings highlight the need for HIV prevention programs that target in-migrants either before or promptly following their relocation.

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Introduction

Migration trends in sub-Saharan Africa

In sub-Saharan Africa, human populations have become increasingly mobile, with numerous overlapping migration patterns.[1] Well-documented migration patterns in the region include rural-urban migration to city centers, circular migration due to labor demand, and migration following environmental degradation or natural disasters.[1-10] In addition to these patterns, sub-Saharan African migrants participate in rural-rural, urban-rural, and urban-urban movements, either internal to country borders or internationally.[1]

In the latter half of the 20th century, sub-Saharan urban centers rapidly grew in size. Initially, the majority of this population growth was due to rural-urban in-migration.[6] Migrants left their rural homes in pursuit of employment and better wages in nearby cities.[1,6] Early in the rural-urban migration wave, these migrants were primarily adult men, but young adult women have since followed.[1,7] The women who migrate to urban centers are typically in their 20s, and are more likely to be unmarried, single, and educated than their counterparts who remain in rural areas.[8] In urban centers, the population influx due to rural-urban migration has exceeded the number of available industry positions, resulting in both chronic unemployment and underemployment.[1,6] There is some indication that the rural-urban migratory influx may be slowing in response to economic recession. The Central Statistics Office of Zambia found that, from 1998 through 2010, there was a decrease in rural-urban movement (following recession in the copper industry) and an increase in rural-rural and urban-urban movements.[2]

Circular migration is a common migration pattern observed in sub-Saharan Africa. This is a type of migration, usually fueled by remote demand for labor, in which migrants alternate residences at regular intervals.[1] For example, circular migration in South Africa was in part

driven by Apartheid-era laws that controlled the movement of black South Africans as well as the demand for labor in South African gold mines.[10] Post-Apartheid, these patterns have remained largely intact. Men from South Africa and surrounding countries continue to migrate to work in mining towns, returning to their original homes periodically.[1,9,10] Circular migration patterns have also developed in response to urbanization in sub-Saharan Africa, with young adults seeking employment in urban centers and periodically returning home to their families in more rural areas.[7,11]

Migration is also common among farmers in sub-Saharan Africa following environmental degradation and reduced agricultural yields. In particular, periods of drought and intense heat cause crops and livestock to perish, leading to increased poverty in families that depend on rain-fed agriculture for income.[2] A recent qualitative study of migrant Tonga-speaking people in Zambia found that poverty resulting from drought was a major reason influencing the decision to migrate.[2] Migration due to environmental degradation is especially well-documented in drought-prone rural Ethiopia.[4,5] Climate change is forecasted to increase temperatures across sub-Saharan Africa, decrease rainfall in southern Africa, and increase rainfall in East Africa, adding an additional layer of uncertainty in forecasting agricultural outcomes and resulting migration in years to come.[3]

Migration and HIV in sub-Saharan Africa

Migration has been associated with the spread of human immunodeficiency virus (HIV) since the origin of the HIV pandemic in Central Africa. A recent reconstruction of early viral dynamics that used archival HIV-1 samples from Zaire (now the Democratic Republic of the Congo) suggested that 1920s Kinshasa acted as a focal point for HIV-1 dissemination across the

country, with the greatest spread occurring along railways and waterways.[12] Faria *et al*. hypothesized that HIV-1 first traveled from southeast Cameroon to Kinshasa, most likely via ferry on the Sangha River system. [12] The HIV-1 M lineage then disseminated through mobile populations, including migrant laborers in the mining industry, on the active railway network connecting Kinshasa to the urban centers of Brazzaville, Lubumbashi, and Mbuji-Mayi. Subtype C of the HIV-1 M lineage appears to have originated in the mining regions of Zaire, and subsequently spread both south and east across the continent.[12] Increasing urbanization and human migration along waterways and railways were key for the initial spread of HIV from areas of endemicity to uninfected regions.[1]

Following the establishment of HIV endemicity across sub-Saharan Africa, human migration patterns have continued to affect HIV spread. In South Africa, for example, the circular migration of men in the mining industry appears to have facilitated HIV spread, both in mining towns and in more rural areas.[13] Adult men left their homes to live and work in the mining towns, and return-migrated to their original homes periodically.[13,14] This system often disrupted stable partnerships at home, and many men engaged in casual sexual relationships while living in the mining towns. [1,10,13,14] These towns saw an influx in sex work as a result.[1] In-depth interviews with 20 male miners and 24 female sex workers living in mining towns revealed that the migrant laborers often had multiple partners at a time and switched partners frequently, both of which are risk factors for HIV acquisition.[14] Cross-sectional surveys of circular migrant and resident men and their partners in South Africa found that migrant men were more likely than resident men to have casual sex partners, to be HIV-positive, and to have been infected with HIV by someone outside of their regular relationships.[13,15] The partners left behind by circular migrants were more likely to have additional sexual partners, compared to

women whose partners were not absent.[15] Thus, Lurie *et al.* hypothesized that the circular migration system in South Africa facilitates HIV transmission both from migrant men to their stable partners at home, and vice versa.[15]

Urbanization across sub-Saharan Africa has spurred a similar type of circular migration pattern, in which both men and women travel to large urban centers for work, typically without their spouses, and periodically return to their rural homes.[16] This pattern has also been associated with HIV transmission. A study that collected sociodemographic data on those living in the rural Zinguinchor region of southwestern Senegal found that 80% of women ages 15-24 and 82% of men ages 20-40 seasonally migrate to large urban centers in Senegal and Gambia. Women are less likely to migrate after they marry, but men continue this pattern into older age.[7] This same study found that those who had moved for one month or longer during the last four months had significantly greater odds of being HIV-positive compared to those who had not migrated (matched OR=4.55, 95% CI: 1.30-16.66).[7] The authors hypothesized that those who migrate acquire HIV from sexual partnerships in urban centers, perhaps due to increased risk behaviors or the disruption of their stable partnerships, then subsequently transmit HIV to their regular partners when they return home.[7] This hypothesis explains the increased HIV prevalence in urban areas, as well as the mechanism of HIV diffusion from urban centers into the surrounding rural areas.[1,7,17]

Multiple studies have found that HIV prevalence tends to be higher in migrants compared to residents, though the relationships between migration status and HIV appear to differ across locations.[11,16,18,19] For example, a longitudinal study that assessed serostatus and risk behaviors of 2,800 couples in Kisesa, rural Tanzania, found that long-term mobile women had a significantly higher HIV prevalence compared to both short-term mobile women and resident women.[16] A

study based in three rural communities in Senegal and Guinea-Bissau found that short-term mobility was associated with higher HIV prevalence among men.[11] A cross-sectional study of the adult population in rural Kilimanjaro, Tanzania, found that both male and female recent in-migrants had more than double the odds of HIV infection compared to residents.[19] A cross-sectional study of adult men in South Africa found that male migrants similarly had more than double the odds of HIV infection compared to residents (OR=2.4, 95% CI: 1.1-5.3).[13] In addition to having increased HIV prevalence, migrants are often diagnosed with HIV later in the course of disease, are less likely to be linked to care or counseling, and are less likely to be taking antiretroviral therapy (ART) compared to residents.[20] Three hypotheses, which are not mutually exclusive, have emerged to explain these discrepancies between migrants and their resident peers.[21,22]

The first hypothesis is that migrants have an increased risk of HIV acquisition because they are people who inherently engage in risk behaviors, regardless of migration status.[21] Several cross-sectional studies have found associations between mobility and risk behaviors, such as having sex with casual partners and having multiple concurrent partners.[11,13,18,23] For example, a cross-sectional survey of men and women living in Yaoundé, Cameroon demonstrated that both married and unmarried men who spent greater than 31 days outside of the city in the past year were more likely to report more than one partner compared to their non-mobile counterparts (adjOR=3.3, 95% CI: 2.0-5.4).[18] In addition, married men who spent greater than 31 days outside of the city in the past year were significantly more likely to report non-spousal partners than those who remained in the city year-round.[18] A study that surveyed men and women at venues where people meet and engage in sexual partnerships in Burkina Faso found that mobile women were more likely to report new sexual partnerships and transactional sex compared to non-

mobile women.[23] From these results, it appears that mobility and risk behaviors for acquiring HIV are intimately linked. What is unclear from these reports, however, is whether these risk behaviors are inherent to migrant populations, or are dynamic and affected by the process of migration itself.

The second hypothesis to explain reports of increased HIV prevalence in migrants is that individuals are more likely to migrate after becoming infected with HIV.[21] In a cohort based in Malawi, Anglewicz *et al.* found that HIV-positive individuals were more likely to migrate compared to HIV-negative individuals. [22,24] The authors hypothesized that this phenomenon was due to marital instability and separation following HIV infection.[22,24] Another study, which followed an open population-based cohort of adults in rural Rakai District, Uganda, from 1990 through 1992, found that a substantial portion of HIV-positive individuals in the cohort out-migrated.[25]

The third hypothesis is that individuals are more likely to become infected with HIV after migrating, as a consequence of moving to a new environment.[21] Two recent longitudinal studies have reported such a phenomenon. The first study used data from a cohort in rural KwaZulu-Natal, South Africa and found that migrants had an increased risk of HIV acquisition following migration.[26] This risk increased as the time spent away from original residence increased, and as the distance traveled during migration increased.[26] The second study, which utilized data from an open population-based cohort in rural Rakai District, Uganda, found that among initially HIV-negative individuals, in-migrants had an increased risk of HIV acquisition compared to residents within first two years following migration.[21]

Migration and HIV in Uganda

Migrants living in Uganda can be divided into two categories: internal migrants and those who have in-migrated from other countries. The majority of internal migrants are voluntary, meaning that they have relocated based on free will. Data collected in 2014 as part of the Uganda Population and Housing Census enumerated 1.4 million recent (arrival <5 years) internal migrants.[27] The Census found that nearly equal numbers of recent internal migrants relocated to urban areas and rural areas.[27] The peak age group that engaged in internal migration was 18-30 years old, followed by 5-17 years old, and there were more female internal migrants than males.[27] 49% of recent internal migrants were married, and 72% reported employment.[27]

In addition to voluntary internal migrants, there are also as many as 2 million involuntary internally displaced migrants living in Uganda. The majority of these persons have been displaced due to a violent 30-year conflict between the central Ugandan government and an insurgent rebel group, the Lord's Resistance Army (LRA).[9,28] Many are members of the Acholi ethnic group, who originated in the northern Ugandan districts where most of the violence has taken place, and have been forced to leave their homes and relocate to government-organized camps.[28] Environmental degradation due to landslides, floods, and droughts has also led to the involuntary displacement of many Ugandans.[9]

The group of in-migrants living in Uganda who originated from other countries contains both refugees and non-refugees. In 2013, there were 531,431 foreign-born people living in Uganda, with the largest portions emigrating from the Democratic Republic of the Congo and South Sudan. Uganda has historically received large numbers of refugees from neighboring countries experiencing civil war and political instability, including Rwanda, Burundi, Eritrea, Ethiopia, Kenya, Nigeria, Pakistan, Somalia, and Sudan.[9] Uganda continues to be a major

destination for refugees. From 2008 through 2012, the largest percentage of refugees came from the Democratic Republic of the Congo, followed by Sudan.[9] Since July of 2016, Uganda has received an influx of refugees, primarily women and children, from South Sudan. As a result, the number of South Sudanese refugees living in Uganda now exceeds 1 million.[29]

In 1994, Quinn set forward three hypotheses to explain the distribution of HIV infection within Uganda, two of which incorporate migration.[1] The first hypothesis states that the current geographical distribution of HIV is the result of HIV dissemination, principally through truck drivers and sex workers, along the major routes connecting urban and rural areas.[1] Supporting evidence for this hypothesis comes from a cross-sectional serosurvey of truck drivers who passed through the same transport depot in Kampala, Uganda, in November 1986.[30] Twenty-four of the 68 truck drivers in the study sample (35%) were found to be HIV-positive. Furthermore, the authors of this study found that 37% of the truck drivers reported more than 50 lifetime sexual partners.[30] The second hypothesis states that HIV dissemination from urban areas to rural areas has been facilitated by returning labor migrants, which has been well-documented in other countries in sub-Saharan Africa.[1,7,11,16] The third hypothesis states that the distribution of HIV infection in Uganda mimics ethnic patterns of recruitment into the Ugandan National Liberation Army, formed in 1979.[1] Quinn believes that all three hypotheses have likely contributed to the current geographical distribution of HIV in Uganda.[1]

In 1995, Nunn *et al*. published a population-based analysis of a cohort of adults, both migrants and residents, living in rural Masaka District in southwestern Uganda. Over a period of four years, the authors of this study assessed HIV seroprevalence and HIV risk behaviors among in-migrants and out-migrants.[31] For those who had in-migrated, location of previous residence was recorded. The majority of in-migrants (71%) had previously lived elsewhere within the

Masaka District. The next highest percentage (11%) came from Kampala. The authors found that recent (arrival < 5 years) in-migration was significantly associated with HIV. In addition, those who in-migrated reported higher lifetime numbers of sexual partners compared to residents.[31]

Three studies have assessed more recent trends in migration and HIV spread in Uganda. These studies utilized data from the Rakai Community Cohort Study (RCCS), an open population-based cohort of persons ages 15-49 living in communities in and near Rakai District in southwestern Uganda.[21,32,33] Rakai District is predominantly rural, but houses major roads that connect the district to urban centers such as Kampala. Both local and international traffic passes through these roads.[33] The first reported AIDS cases in Uganda were identified in Rakai, and the district now has a generalized HIV epidemic.[33,34]

The first study, by Schuyler *et al*., assessed trends in migration over the period between 2001 and 2011 among youth ages 15-24 in the RCCS.[33] Over the course of the study period, out-migration among youth significantly increased. Those in the younger age category, 15-19 years old, out-migrated at a greater rate than those in the 20-24 year-old category. In-migrants were significantly more likely to be women and to be 20-24 years old compared to residents. Overall, migrants reported moving for work and to live with friends or relatives most frequently. Young women, in particular, frequently reported migrating for a new marriage. Seventy-three percent of in-migrants moved from within the Rakai District, and 10% in-migrated from Masaka District, which borders Rakai District to the north. Both male and female in-migrants in this study reported a higher prevalence of risk behaviors associated with HIV transmission and acquisition. Young male in-migrants were significantly more likely to report alcohol use in the last 30 days, ever having a sexual experience, multiple sexual partnerships, and inconsistent condom use compared to young male residents. Young female in-migrants were significantly more likely to

report alcohol use in the last 30 days, ever having a sexual experience, multiple sexual partnerships, concurrent sexual partnerships, and inconsistent condom use compared to young female residents.[33]

A second study, by Olawore *et al.*, assessed HIV incidence among initially HIV-negative in-migrants in the RCCS from 1999 through 2015.[21] In contrast to the previously discussed study by Schuyler *et al*., the authors of this study collected and analyzed data on persons ages 15-49. In-migrants were categorized as those who migrated into RCCS study communities between survey rounds. The majority (69%) of in-migrants in the study were female, and in-migrants were more likely to have technical or university education. 57% of in-migrant men and 67% of in-migrant women moved from communities within the Rakai District. Outside of the Rakai District, in-migrants came predominantly from the neighboring Masaka District and Kampala. Female and male in-migrants cited different reasons for migration. Among women, the most common reasons for migration were to live with a friend or relative (36%), to move in with a married or consensual partner (37%), and to work (20%). In contrast, the majority of men reported migrating for work (45%) or to start a new household (29%). In-migrant men and women were significantly more likely to report HIV risk behaviors, including sexual relationships with partners outside their communities and higher numbers of recent sexual partners compared to residents. In-migrants who reported non-marital partnerships also reported significantly lower rates of consistent condom use compared to residents. The major finding of this study was that initially HIV-negative in-migrants of both genders had an increased risk of HIV acquisition during the two years following their move (Female adjIRR=2.35, 95% CI: 1.61-3.42; Male adjIRR=1.89, 95% CI: 1.56-3.19). This risk decreased after a two-year period and subsequently approached the HIV risk for residents.[21]

A third recent study, by Grabowski *et al*., used data from two RCCS survey rounds to map participants' migratory movements between communities, taking into account the HIV prevalence in the communities involved.[32] This study found that migration was more common among women than men, and occurred most frequently among those ages 15-24. The majority of in-migrants moved from other communities within Rakai District (54%), followed by communities in Masaka District. In-migrant women were significantly more likely to be HIV-positive compared to non-migrant women (adjPRR=1.45, 95% CI: 1.31-1.60), and accounted for 40% of all newly identified infections in the second survey round. Contrary to the "source-sink hypothesis," which states that individuals migrating from areas of higher HIV prevalence serve as sources of infection to areas of lower HIV prevalence, this study found that HIV-positive migrants tended to move to areas of higher HIV prevalence, such as fishing communities. Thus, the in-migrants (particularly female in-migrants) may be assortatively mixing by HIV status at a community-level.[32]

The results of these three studies shed light on the interplay between migration, risk behaviors, and HIV incidence in Rakai District, Uganda. In-migrants, who are most likely to be women ages 20-24 moving from a nearby community, have an increased risk for HIV acquisition during the first two years after moving to a new location. In-migrants tend to engage in risk behaviors associated with HIV acquisition and transmission and mix according to HIV status at a community-level.[21,32,33] Because HIV-negative individuals are at a higher risk for HIV infection immediately following in-migration, and because migrants appear to sort based on HIV status, the partner pool of in-migrants is of interest. Who do in-migrants partner with immediately following migration? What are the demographics and risk behaviors of the individuals in this partner pool, and what is this pool's untreated HIV prevalence? In order to fully characterize the

risk facing recent in-migrants, we used data on sexual partnerships in Rakai, Uganda to answer these questions.

In-migrant partner pools in sub-Saharan Africa

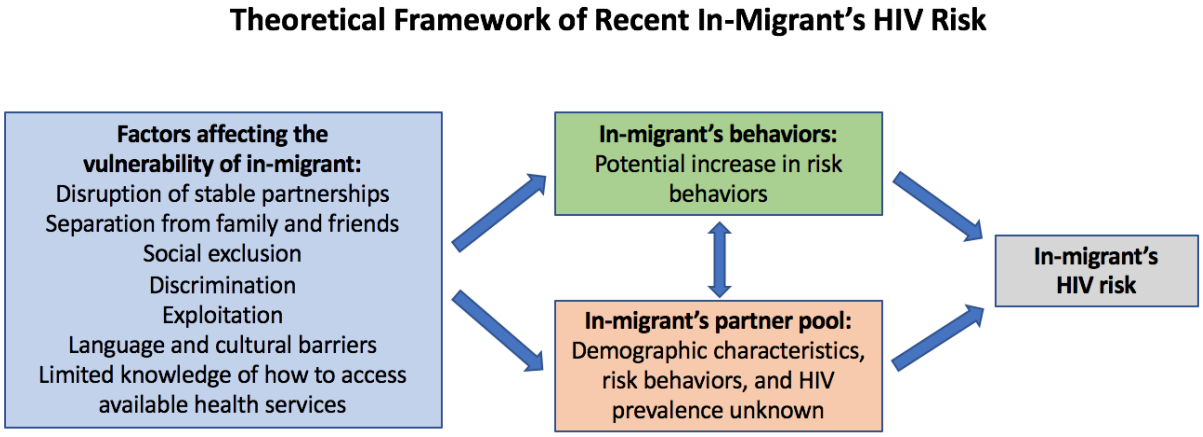
A partner pool is a collection of potential sexual partners for any given individual, based on who that individual preferentially mixes with. Partner pools can be represented by sexual networks, in which individuals are connected through concurrent sexual partnerships.[35,36] If an uninfected individual joins a sexual network (i.e. through in-migration), that person's risk of HIV acquisition is affected by demographic factors, sexual risk behaviors, the overall structure of the network, and that person's position within the network.[35,37] Furthermore, the uninfected individual's HIV risk is affected by the HIV prevalence within the sexual network.[37,38] If an individual joins a network in which a large proportion of individuals are already infected, the likelihood that this individual will form a partnership with someone who can potentially infect them is greater than if the individual entered a network with a lower disease prevalence. In this way, the prevalence of disease affects subsequent incidence of disease among the naïve individuals entering a network.

Three studies of migration in sub-Saharan Africa have collected data on migrants' partners directly.[13,15,16] However, the partners assessed in these studies were those left behind by out-migrants. For example, in a study of male migrant miners in South Africa, Lurie *et al*. collected data on the female partners left behind by male out-migrants instead of the women that the migrants associated with in mining towns.[15] In a study of couples living in rural Kisesa, Tanzania, Kishamawe *et al*. similarly focused on the partners of out-migrants, though partners of both genders were studied.[16] Thus, some information is known about migrants' partner pools

prior to migration, but little is known about migrants' partner pools following migration in sub-Saharan Africa.

Theoretical framework

In examining the risk of HIV acquisition in the 2-year period following in-migration in sub-Saharan Africa, we have created following theoretical framework.



Factors affecting the vulnerability of individuals following migration include the disruption of stable partnerships, discrimination, exploitation, and limited knowledge of how to access health services.[9,21,33] These factors may in turn affect the types of people that in-migrants interact with (particularly if in-migrants experience social exclusion or exploitation), and therefore their partner pools. In addition, these factors may be related to an increase in risk behaviors post-migration.[21] Depending on the characteristics, risk behaviors, and HIV prevalence in the partner pool that the in-migrant joins, the partner pool itself may also affect the in-migrant's risk behaviors. The HIV prevalence in the partner pool confers an additional, independent risk to the

in-migrant.[37] Through these theorized mechanisms, the in-migrant's HIV risk is heightened for a period of time post-migration.

Rakai Community Cohort Study

The Rakai Community Cohort Study (RCCS) is an open population-based cohort of persons ages 15-49 living in communities in and near Rakai District in rural southwestern Uganda. HIV incidence in the RCCS has decreased 42% following the scale up of combination HIV prevention, including antiretroviral therapy and medical male circumcision, in the region.[39] However, this decrease in incidence has not been observed among recent in-migrants in the cohort.[21] We believe that the consistently high HIV incidence among recent in-migrants is in part due to the in-migrants' partner pools, which may fundamentally differ from the partner pools of other members in the cohort. The RCCS collects egocentric data on the recent partners of survey participants, as well as the sexual risk behaviors exhibited during these partnerships. The names of cohabitating sexual partners are also collected, enabling linkage between a subset of self-reported, stable partners. Here, we used self-reported data from in-migrants and residents in the RCCS to 1) compare the partner characteristics of in-migrants and residents and 2) estimate the prevalence of untreated HIV infection among the partner pools of in-migrants and residents using data from linked partners. Because of the increased HIV acquisition observed among in-migrants, we hypothesize that in-migrants and their partners practice more sexual risk behaviors than do residents and their partners. Additionally, we hypothesize that the prevalence of untreated HIV infection is higher in the partner pool of in-migrants compared to that of residents.

Methods

Study population

The Rakai Community Cohort Study (RCCS) is conducted in rural Rakai District, Uganda by the Rakai Health Science Program (RHSP).[39] The study was initiated in 1994 and is currently ongoing. At approximately 18 month intervals, household censuses enumerate all residents in a study community and collect demographic data. During each census, all births, deaths, in-migrations, and out-migrations that have occurred in a study community since the previous census are recorded. In-migrant participants are classified as those migrate into a study community between survey rounds. Individuals eligible for RCCS surveys must be residents within study boundaries, aged 15 through 49 years, and capable of providing informed consent.

Following the census, eligible participants are interviewed regarding sociodemographic characteristics, sexual behaviors, health-seeking behaviors, and male circumcision status. ART use is defined by self-report, which has been previously validated in the RCCS.[50] Participants are also interviewed about their four most recent partners in the last year. Detailed information is collected on the nature of these partnerships, such as relationship type and duration, as well as characteristics of the partner, such as partner occupation and age. Additionally**, t**he RCCS collects the names of cohabitating sexual partners at time of census and survey. When a named partner also participates in the RCCS, the couple's data are linked. All consenting participants provide venous blood samples, which are tested for HIV (see Laboratory methods).

For this study, we used data collected from participants in 30 continuously surveyed communities between April 6, 1999 and September 2, 2016. This period included 12 survey rounds. Participation rates among eligible individuals ranged from 59% to 66% between surveys.[39] Participation was lower among men, younger residents, and residents living in trading

communities.[39] The RCCS was approved by the Uganda National Council for Science and Technology, the Uganda Virus Research Institute Research and Ethics Committee, and the Western Institutional Review Board (Olympia, WA).

Scale-up of combination HIV prevention

The RCCS's combination HIV prevention (CHP) strategy consists of antiretroviral therapy (ART) and voluntary medical male circumcision (VMMC) services. ART was introduced to Rakai in 2004 with funding from the U.S. President's Emergency Plan for AIDS Relief (PEPFAR). Since this time, RHSP has provided ART to Rakai residents through mobile and static clinics. ART initiation criteria changed over the course of this study, from <250 cells/mm^3 in 2004, to <350 cells/mm^3 in 2011, to <500 cells/mm^3 in 2014. Additionally, since 2014, RHSP has provided ART to pregnant and breastfeeding women, serodiscordant couples, and priority populations (such as sex workers, fisherfolk, and truckers).

From 2003 through 2006, RHSP conducted a large randomized controlled trial to assess the efficacy of male circumcision (MC).[40] Following the conclusion of the trial, RHSP provided free VMMC services to trial controls. Since 2007, with PEPFAR support, the RHSP has provided free VMMC services to males ages 13 and older throughout the district.

For this study, we stratified time in relation to the scale-up of CHP. The time period prior to availability of VMMC and ART programs included survey rounds 1 through 5 (1999-2004), and was denoted as the Pre-CHP period (see Supplementary Table 2). Survey rounds 6 through 9 (2004-2011) were denoted as Early CHP and survey rounds 10 through 12 (2011-2016) were denoted as Late CHP.

Laboratory methods

Participants provide venous blood samples for rapid HIV testing. Prior to October 2011, enzyme immunoassays (EIAs) were used to test for HIV, with confirmation by Western blot.[41] In October 2011, a parallel three test rapid testing algorithm was introduced to identify HIV-positive participants.[42] Two EIAs (Vironostika HIV-1, BioMerieux, and Recombigen, Cambridge Biotech) are performed to confirm rapid test positives. If discordant EIA results are obtained, Western blot (GS HIV-1 Western Blot, Bio-Rad Laboratories, Redmond, WA, USA, BioMerieux-Vitek) or PCR is used to determine seropositivity.[43]

Statistical analysis

Using egocentric network data, we compared self-reported characteristics of the partners of in-migrants and residents irrespective whether the HIV serostatus of partners was known. These characteristics included age, age difference, primary occupation, relationship type, relationship length, whether the relationship was ongoing at time of survey, residence in household/community, circumcision status, condom use, partner's alcohol use before sex, RCCS participant's alcohol use before sex, partner's knowledge of RCCS participant's HIV status, and RCCS participant's knowledge of their partner's HIV status. Analyses were stratified by gender and HIV serostatus. Pearson's chi-square tests were used to compare categorical variables, and Mann-Whitney U tests were used to compare continuous variables.

Among those cohabitating partnerships where the HIV serostatus of both partners was known, we estimated the prevalence of untreated HIV infection in the male and female partners of female and male migrant and residents, respectively. Specifically, log-binomial regression with generalized estimating equations was used to measure the risk of partnership with one or

more untreated HIV-positive partners comparing in-migrants with residents. This analysis was also stratified by calendar period (Pre-CHP, Early CHP, Late CHP, and survey round 12; see Supplementary Table 2). Multiple within-participant correlation structures, including independent, exchangeable, and autoregressive 1, were assessed. The final working correlation structure was selected using quasi-likelihood information criterion. For cases in which log-binomial models did not converge, we used Poisson regression with robust variance.[44]

We also examined whether in-migrants were more likely to be HIV-positive and untreated HIV-positive compared to residents. Restricting to HIV-positive RCCS participants, we explored whether in-migrants were less likely to be on ART compared to their resident peers. Finally, we examined whether in-migrants were more likely than residents to partner with in-migrants, and whether they were more likely than residents to partner with someone of the same migration status. These analyses were also conducted using log-binomial regression.

Results

Characteristics of the partners of in-migrants and residents

In total, 116,749 sexual partners were reported by 29,423 RCCS participants (Table 1). Of these partners, 56,195 (48%) were male partners reported by female RCCS participants (n=16,911), and 60,554 (52%) were female partners reported by male RCCS participants (n=12,512). In-migrants reported 15,570 (13%) partners, and residents reported 101,179 (87%) partners. HIV-negative participants reported 100,133 (86%) sexual partners and HIV-positive participants reported the remaining 16,616 (14%) (Tables 2 and 3, respectively).

The sexual partners of in-migrants tended to be younger than those reported by residents irrespective of gender (Table 1). The female-reported median age of male sexual partners was 28 years (IQR: 24-34) among in-migrant women compared to 33 years (IQR: 27-40) among resident women ($p<0.0001$). Sexual partners of in-migrant women were also twice as likely to be between the ages of 20-24 years compared to the partners of resident women (21% versus 10%, $p<0.0001$).

Among men, the self-reported median age of female sexual partners was 23 years among in-migrants (IQR: 19-27) compared to 24 years (IQR: 20-30) among residents ($p<0.0001$). Among women, the median age difference between women and their self-reported male partners was 4 years (IQR: 2.0-7.0) irrespective of migration status. Similar trends were seen among men. However, a somewhat larger percentage of the female partners reported by resident men were younger (76%) than the partners reported by in-migrant men (71%, $p<0.0001$).

The most common primary occupation among self-reported sexual partners was agriculture irrespective of gender. However, the partners of in-migrants were less likely to have agricultural work as a primary occupation compared to the partners of residents (19% versus

26% for male partners, p<0.0001; 22% versus 35% for female partners, p<0.0001). Additionally, the partners of in-migrant men were more likely to have housework as a primary occupation compared to the partners of resident men (21% versus 15%, p<0.0001). Beyond these distinctions, there were no meaningful differences comparing the occupations of in-migrants' partners to those of residents' partners.

The sexual partners of in-migrants were significantly less likely to be marital partners compared to the partners of residents (23% versus 42% for male partners, p<0.0001; 18% versus 29% for female partners, p<0.0001). In contrast, in-migrants' partners were more likely to be stable cohabitating partners (39% versus 25% for male partners, p<0.0001; 22% versus 19% for female partners, p<0.0001) and boyfriends/girlfriends (35% versus 31% for male partners, p<0.0001; 48% versus 43% for female partners, p<0.0001). The partners of in-migrants were also somewhat more likely to be casual partners compared to the partners of residents (1.8% versus 0.85% for male partners, p<0.0001; 9.9% versus 6.6% for female partners, p<0.0001).

The median duration of sexual partnerships reported by migrants was shorter compared to that reported by residents. Among in-migrant women, partnerships had a median duration of 1.0 year (IQR: 0.82-4.0) compared to 6.0 years (IQR: 3.0-13) for residents (p<0.0001). Partnerships reported by in-migrants were also slightly less likely to be ongoing compared to the partnerships of residents (80% versus 84% for male partners, p<0.0001; 62% versus 71% for female partners, p<0.0001). Additionally, the partners of in-migrants were less likely to live in the same household and were more likely to be from an outside community (23% versus 19% for male partners, p<0.0001; 29% versus 25% for female partners, p<0.0001).

The relationships between migration status and known HIV risk factors varied. The male partners of in-migrant women were more likely to be circumcised compared to the partners of

resident women (43% versus 36%, p<0.0001), and in-migrant women were less likely to report never using a condom with their partners (63% versus 68%, p<0.0001). There were no meaningful differences in the proportion of individuals who used alcohol with their partners by resident status. Notably, in-migrants of both genders were less likely to know their partner's HIV status compared to residents (49% versus 55% for males, p<0.0001; 59% versus 63% for females, p<0.0001). They were also less likely to have told their partners their HIV status compared to residents (33% versus 39% for males, p<0.0001; 46% versus 49% for females, p=0.00612). In-migrants of both genders were more likely to have never been previously tested for HIV and received HIV test results (25% versus 12% for males, p<0.0001; 12% versus 5.7% for females, p<0.0001) and were less likely to have received couples counseling for HIV (16% versus 21% for males, p<0.0001; 25% versus 30% for females, p<0.0001).

Results were similar when stratified by the HIV-status of the RCCS participant with some exceptions (Tables 2-3). While HIV-negative in-migrant men were less likely to know their partner's HIV status (51% versus 56%, p<0.0001) and were less likely to have shared their HIV status with their partner (34% versus 40%, p<0.0001) compared to residents, there were no such differences between in-migrant and resident women. Among HIV-positive women, there were no differences in partnership duration or the proportion of partnerships ongoing by migration status. HIV-positive in-migrant men were more likely to report never using condoms with their partner compared to HIV-positive resident men (60% versus 48%, p<0.0001). Additionally, HIV-positive in-migrant women were more likely to report using alcohol before sex with their partner compared to HIV-positive resident women (34% versus 27%, p=0.00719). HIV-positive in-migrant men were also more likely to report that their partner uses alcohol before sex compared to HIV-positive resident men (41% versus 30%, p=0.000781).

Untreated HIV prevalence in the partner pools of in-migrants and residents among linked couples in the RCCS

There were 13,708 study participants (n=7,368 women; 6,340 men) in a named partnership with at least one other RCCS participant. These linked couples (n=7,558) contributed 21,140 couple-visits, and comprised 47% (n=13,708/29,423) of all study participants who self-reported at least one sexual partnership. Within couples, 4,647 (34%) participants were classified as in-migrants and 2,333 (17%) were either HIV-positive at their first RCCS study visit or seroconverted during follow-up. There were 6,281 HIV-negative women (n=18,423 couple-visits), 5,505 HIV-negative men (n=17,611 couple-visits), 1,090 ART-naïve HIV-positive women (n=1,090 couple-visits), and 956 ART-naïve HIV-positive men (n=1,985 couple-visits) among these couples.

Assortative mixing by migration status

We observed a pattern of assortative mixing by migration status among in-migrants and residents in linked partnerships (see Supplementary Table 3). In-migrant women were nearly 21 times more likely than resident women to partner with another in-migrant (PRR=20.92, 95% CI: 18.56-23.67). In-migrant men were more than 7 times more likely than resident men to partner with an in-migrant woman (PRR=7.28, 95% CI: 6.94-7.64).

Untreated HIV prevalence in the partner pools of HIV-negative in-migrants and residents

Figure 1 shows the prevalence of untreated HIV infection among the partners of in-migrants and residents among linked couples at each study visit between 1999 and 2016. Figures 1A and 1B show the prevalence over calendar time among the partners of HIV-negative women

and men, respectively, stratified by migration status. Over the study period, the prevalence of untreated HIV infection among the partners of HIV-negative in-migrant women ranged from 10.3% (95% CI: 5.5-15.0%) in 2000 to 3.4% (95% CI: 1.5-5.2%) in 2016. Prevalence of untreated HIV in the partners of HIV-negative resident women was generally lower, ranging from 5.9% (95% CI: 4.3-7.4%) in 1999 to 2.1% (95% CI: 1.4-2.9%) in 2014. Prevalence of untreated HIV among female partners of HIV-negative in-migrant men ranged from 9.5% (95% CI 3.6-15.4%) in 2002 to 1.9% (95% CI: -0.2-4.0%) in 2016 and among resident men from 5.2% (95% CI: 3.4-6.5%) in 1999 to 2.2% (95% CI: 1.5-2.8%) in 2016.

The prevalence of untreated HIV was higher among the male partners of HIV-negative in-migrant women compared to those of HIV-negative resident women at all study visits. The discrepancy between the partners of in-migrant women and those of resident women peaked between 2011 and 2014 and subsequently declined. A similar relationship between migration status and untreated HIV prevalence was observed among HIV-negative men. From 2000 through 2014, the untreated HIV prevalence among female partners of HIV-negative in-migrant men was higher than that observed among HIV-negative resident men. After 2012, the discrepancy between the partners of in-migrant and resident men decreased.

Overall, we found that in-migrant status was associated with an increased risk of partnership with one or more untreated HIV-positive persons among HIV-negative men and women (Table 4). Between 1999 and 2016, HIV-negative in-migrant women were 55% more likely to partner with one or more untreated HIV-positive persons, compared to HIV-negative resident women (PRR=1.55, 95% CI: 1.30-1.85). Similarly, HIV-negative in-migrant men were 74% more likely to partner with one or more untreated HIV-positive women compared to HIV-negative resident men (PRR=1.74, 95% CI: 1.40-2.17).

Stratification by time period (Pre-CHP, Early CHP, and Late CHP) showed that the absolute risk of partnership with one or more untreated HIV-positive persons among HIV-negative residents decreased following the scale-up of CHP. The discrepancies between in-migrants and residents of both genders were smallest during the period prior to CHP scale-up (Pre-CHP, 1999-2004). The discrepancy between HIV-negative in-migrant and resident women grew during Early CHP (2004-2011) (PRR=1.57, 95% CI: 1.19-2.07) and was greatest during Late CHP (2011-2016) (PRR=1.95, 95% CI: 1.43-2.65). However, when analysis was restricted to the final survey round (2014-2016, the last two years of Late CHP), there were no significant differences between HIV-negative in-migrant and resident women for partnership with one or more untreated HIV-positive persons (PRR=1.49, 95% CI: 0.79-2.82). The discrepancy between HIV-negative in-migrant and resident men was greatest during Early CHP (PRR=1.91, 95% CI: 1.36-2.70), and remained significant during Late CHP (PRR=1.81, 95% CI: 1.22-2.68). However, when analysis was restricted to the final survey round, there were no significant differences between HIV-negative in-migrant and resident men for partnership with one or more untreated HIV-positive persons (PRR=0.85, 95% CI: 0.27-2.73).

Untreated HIV prevalence in the partner pools of untreated HIV-positive in-migrants and residents

Figures 1C and ID show untreated HIV prevalence over time among the partners of untreated HIV-positive men and women stratified by migration status. Prevalence among the partners of untreated HIV-positive individuals was significantly higher than that among the partners of HIV-negative individuals. Over the study period, untreated HIV prevalence in the partners of untreated HIV-positive in-migrants ranged from 71.4% (95% CI: 51.2-90.8%) in

2003 to 17.4% (95% CI: 1.9-32.9%) in 2016. Prevalence in the partners of resident women ranged from 70.2% (95% CI: 62.4-78.1%) in 2002 to 32.1% (95% CI: 21.7-42.4%) in 2014. The untreated HIV prevalence in the partners of untreated HIV-positive in-migrant men ranged from 85.7% (95% CI 59.8-111.6%) in 2003 to 20.0% (95% CI: -0.2-40.2%) in 2016. Lastly, prevalence in resident men ranged from 61.1% (95% CI: 53.6-68.6%) in 2000 to 27.1% (95% CI: 18.2-36.0%) in 2016. Figures 1C and ID demonstrate similar trends in both genders: prevalence decreased in the partners of in-migrants and residents over time. Overall, the untreated HIV prevalence among partners of untreated HIV-positive individuals did not significantly differ by migration status in women or men.

Over the course of the study, untreated HIV-positive in-migrant women were slightly less likely to partner with one or more untreated HIV-positive persons compared to untreated HIV-positive resident women (PRR=0.87, 95% CI: 0.78-0.96). This slight decrease in risk was present during the Pre-CHP time period but not after. There were no significant differences between untreated HIV-positive in-migrant and resident women for partnership with one or more untreated HIV-positive persons during Early CHP, Late CHP, and the final survey round. Between 1999 and 2016, there were no significant differences between untreated HIV-positive in-migrant and resident men for partnership with one or more untreated HIV-positive partners (PRR=1.06, 95% CI: 0.92-1.21).

HIV status and treatment status among in-migrants and residents

Over the course of the study, in-migrant women were significantly more likely to be HIV-positive compared to resident women (PRR=1.30, 95% CI: 1.19-1.42). There were no significant differences between in-migrant men and resident men for risk of being HIV-positive

(PRR=1.07, 95% CI: 0.93-1.22). However, following the scale-up of CHP, HIV-positive in-migrants of both genders were significantly less likely to be on ART compared to HIV-positive residents (Female PRR= 0.55, 95% CI: 0.44-0.66; Male PRR=0.47, 95% CI: 0.31-0.66).

Discussion

In our observational cohort study, we found an increased frequency of sexual risk behaviors in the partnerships of in-migrants compared to the partnerships of residents. The partnerships of in-migrants tended to be shorter in duration and were more likely to be non-marital partnerships compared to the partnerships of residents. Additional risk behaviors included partnering with someone from an outside community,[43] nondisclosure of HIV status, and not knowing a partner's HIV status. Other sexual risk behaviors, including never using condoms and drinking alcohol before sex, were observed at a greater frequency among HIV-positive in-migrants compared to HIV-positive residents. Our findings are consistent with previous reports of increased sexual risk behaviors in the partnerships of migrants compared to those of residents in sub-Saharan Africa.[21,33] The increased sexual risk behaviors that we observed among in-migrants likely contribute to their increased HIV acquisition. However, we believe that these risk behaviors do not fully explain in-migrants' increased HIV acquisition, as Olawore *et al*. found that in-migrant status was associated with increased HIV acquisition in the RCCS even after adjustment for sexual behaviors.[21]

Following relocation, in-migrants experience increased vulnerability due to the disruption of stable partnerships, separation from family and friends, discrimination, language and cultural barriers, and limited knowledge of how to access health services.[9,33,47] In-migrants' unfamiliarity with their new community members may contribute to some of their increased sexual risk behaviors, such as partnership with non-marital partners, HIV status nondisclosure, and partnering with individuals who don't disclose their HIV statuses. This unfamiliarity may also cause in-migrant females to be more vulnerable to sexual exploitation.[47] It is unclear whether in-

migrants' sexual risk behaviors remain frequent or decrease over time as they have the ability to build closer relationships with community members.

Among linked long-term, cohabitating partnerships, we found that HIV-negative in-migrants were more likely than HIV-negative residents to engage in high-risk partnerships with untreated HIV-positive individuals, irrespective of the scale-up of combination HIV prevention. Within this subset, we estimated a higher prevalence of untreated HIV infection in the partner pool of HIV-negative in-migrants compared to that of HIV-negative residents. Contrastingly, the prevalence of untreated HIV did not differ greatly in the partners of untreated HIV-positive in-migrants and residents. To our knowledge, the prevalence of untreated HIV in the partner pool of sub-Saharan African in-migrants has not previously been estimated. Our findings suggest that the increased HIV acquisition observed in the RCCS among in-migrants[21] is driven in part by a higher prevalence of serodiscordant relationships consisting of HIV-negative in-migrants and untreated HIV-positive partners. The risk of HIV transmission is much higher in these relationships compared to those in which the HIV-positive partner achieves viral suppression through ART, particularly if protective measures (i.e., condoms, pre-exposure prophylaxis) are not used.[45,46]

Within long-term cohabitating couples, we observed assortative mixing by migration status among in-migrants and residents. As observed in previous studies,[7,16,19,20,31,32] we also found in that in-migrant females in this subset were more likely to be HIV-positive compared to resident females and that HIV-positive in-migrants were less likely to be on ART compared to their resident peers (regardless of CHP scale-up). It is unclear if in-migrants are less likely to be on ART because relocation interrupts treatment, because they are a hard-to-reach population, or because they are inherently less likely to access HIV treatment and prevention services.[32] Taken

together, the increased HIV prevalence, decreased likelihood of ART use, and assortative mixing by migration status observed among in-migrants may partially explain the increased untreated HIV prevalence in the cohabitating partners of in-migrants.

Our findings highlight the need for HIV prevention and treatment programs in sub-Saharan Africa that either accompany in-migrants or capture them promptly following relocation. It has been demonstrated that pre-exposure prophylaxis (PrEP) is an effective and feasible method for the prevention of HIV transmission in East African serodiscordant couples.[48] PrEP, taken during the migration process and following relocation, may reduce HIV risk among mobile persons. However, at this time PrEP is not widely available in Uganda and elsewhere in sub-Saharan Africa, and no implementation studies have been conducted to assess PrEP's effectiveness in sub-Saharan African in-migrant populations specifically. RHSP is currently exploring the use of community health workers to assist with the linkage of in-migrants to HIV treatment and prevention services. If this program is implemented, the community health workers will locate and visit in-migrants shortly after their arrival, provide them with welcome packages, and inform them about local health services (including HIV treatment and prevention services). A community health worker approach may increase linkage to HIV treatment and prevention[49] among in-migrants, and may additionally reduce in-migrants' experiences of social discrimination and detachment. However, effective delivery of HIV treatment and prevention services to mobile populations remains a significant challenge.[20]

There were several limitations in this study. First, our subsample of linked partnerships consisted of household-based marital and long-term consensual unions which are not representative of all in-migrants' relationships. Secondly, ART use among in-migrants and residents was self-reported and therefore subject to reporting bias. However, a previous

validation study conducted in the RCCS found that self-reports of ART use had a high specificity (99%) and sensitivity (77%) when compared to a gold standard of antiretroviral drug detection in plasma.[50] Lastly, through the use of census data, we were unable to identify circular and short-term migrants. Thus, we did not assess the partnerships and sexual risk behaviors of these migrant populations specifically.

While previous studies have estimated HIV prevalence in the among partners left behind by circular migrants and out-migrants,[13,15,16] ours is the first study to characterize the partner pool of sub-Saharan African in-migrants following relocation. Our household census uniquely enabled us to link a subset of cohabitating, long-term sexual partners. As a result, we were able to assess data self-reported by partners in conjunction with data collected directly on the partners as part of their participation in the RCCS. In the future, we aim to impute the prevalence of untreated HIV in our larger dataset of partners reported by RCCS participants, including partners who are not RCCS participants.

In conclusion, we observed an increased frequency of sexual risk behaviors in the partnerships of in-migrants compared to the partnerships of residents. Among a subset of linked, cohabitating couples, we demonstrated that the prevalence of untreated HIV in the partners of HIV-negative in-migrants was significantly higher than that of their resident peers. We believe that the increased untreated HIV prevalence in the partner pool of in-migrants, combined with increased sexual risk behaviors and assortative mixing patterns, likely contributes to the heightened risk of HIV acquisition observed among in-migrants in the RCCS. Our findings highlight the need for programs that effectively link in-migrants to HIV treatment and prevention services immediately following relocation.

Table 1: Characteristics of self-reported partners and partnerships of RCCS participants, 1999-2016

	Self-reported Male Partners (n=56195)			Self-reported Female Partners (n=60554)		
	Reported by Resident Females (n=46873)	**Reported by In-Migrant Females (n=9322)**	**P-value**	**Reported by Resident Males (n=54306)**	**Reported by In-Migrant Males (n=6248)**	**P-value**
Median partner age (IQR)	33 (27, 40)	28 (24, 34)	<0.0001	24 (20, 30)	23 (19, 27)	<0.0001
Partner age category						
15-19	3.3% (1231/37563)	3.7% (253/6754)	0.0530	22% (9290/42935)	23% (1025/4456)	0.0372
20-24	10% (3841/37563)	21% (1429/6754)	<0.0001	26% (11139/42935)	31% (1391/4456)	<0.0001
25-29	16% (6000/37563)	23% (1536/6754)	<0.0001	19% (8368/42935)	19% (837/4456)	0.265
30-34	17% (6360/37563)	16% (1051/6754)	0.00577	12% (5154/42935)	8.8% (391/4456)	<0.0001
35-39	14% (5203/37563)	8.9% (602/6754)	<0.0001	6.7% (2893/42935)	4.1% (181/4456)	<0.0001
40 or older	23% (8765/37563)	9.8% (659/6754)	<0.0001	4.0% (1721/42935)	2.7% (119/4456)	<0.0001
Don't know	16% (5953/37563)	16% (1113/6754)	0.198	4.1% (1741/42935)	4.4% (198/4456)	0.228
Missing	0.56% (210/37563)	1.6% (111/6754)	<0.0001	6.1% (2629/42935)	7.0% (314/4456)	0.0165
Median age difference between partner and RCCS participant (IQR)	4.0 (2.0, 7.0)	4.0 (2.0, 7.0)	0.119	-4.0 (-7.0, -2.0)	-3.0 (-6.0, -1.0)	<0.0001
Partner age compared to RCCS participant's age						
Younger	4.2% (1584/37563)	4.0% (272/6754)	0.494	76% (32600/42935)	71% (3184/4456)	<0.0001
Same age	6.4% (2395/37563)	6.6% (445/6754)	0.529	8.2% (3538/42935)	9.6% (428/4456)	0.00192
Older by less than 5 years	36% (13688/37563)	34% (2323/6754)	0.00134	4.7% (2014/42935)	6.2% (277/4456)	<0.0001
Older by 5 to less than 10 years	23% (8537/37563)	23% (1571/6754)	0.344	0.75% (323/42935)	0.76% (34/4456)	0.999
Older by 10 or more years	14% (5196/37563)	14% (919/6754)	0.634	0.21% (90/42935)	0.47% (21/4456)	0.00105
Don't know	16% (5953/37563)	16% (1113/6754)	0.198	4.1 (1741/42935)	4.4% (198/4456)	0.228
Missing	0.56% (210/37563)	1.6% (111/6754)	<0.0001	6.1% (2629/42935)	7.0% (314/4456)	0.0165
Partner's primary occupation						
Agricultural work	26% (12334/46873)	19%(1805/9322)	<0.0001	35% (18857/54306)	22% (1378/6248)	<0.0001
Housework	0.16% (73/46873)	0.27% (25/9322)	0.0251	15% (8316/54306)	21% (1281/6248)	<0.0001
Bar or restaurant work	0.47% (218/46873)	0.40% (37/9322)	0.418	2.3% (1229/54306)	3.6% (225/6248)	<0.0001
Government, clerical, or teaching work	9.5% (4444/46873)	9.7% (902/9322)	0.571	3.9% (2109/54306)	5.0% (312/6248)	<0.0001
Student	2.2% (1015/46873)	1.7% (156/9322)	0.00272	12% (6627/54306)	12% (779/6248)	0.559
Shopkeeper	5.7% (2656/46873)	5.0% (467/9322)	0.0123	4.6% (2479/54306)	5.3% (329/6248)	0.0138
Trader or vender	21% (9827/46873)	18% (1710/9322)	<0.0001	3.5% (1896/54306)	4.6% (285/6248)	<0.0001
Trucker	4.4% (2072/46873)	5.0% (470/9322)	0.00907	0.0% (0/54306)	0.0% (0/6248)	0.999
Hair dresser or salon owner	0.34% (161/46873)	0.73% (68/9322)	<0.0001	1.8% (968/54306)	3.0% (188/6248)	<0.0001
Construction	3.7% (1728/46873)	4.3% (402/9322)	0.00424	0.0% (0/54306)	0.016% (1/6248)	0.192
Other	23% (10565/46873)	26% (2444/9322)	<0.0001	5.1% (2789/54306)	6.6% (411/6248)	<0.0001
Unemployed	0.10% (45/46873)	0.054% (5/9322)	0.288	<0.01% (1/54306)	0.0% (0/6248)	0.999
Don’t know	0.33% (154/46873)	0.46% (43/9322)	0.0595	0.24% (132/54306)	0.37% (23/6248)	0.0854
Missing	3.4% (1581/46873)	8.5% (788/9322)	<0.0001	16% (8903/54306)	17% (1036/6248)	0.719
Relationship type						
Current husband/wife	42% (19809/46873)	23% (2166/9322)	<0.0001	29% (15902/54306)	18% (1118/6248)	<0.0001
Current cohabitating partner (non-marital)	25% (11596/46873)	39% (3593/9322)	<0.0001	19% (10361/54306)	22% (1374/6248)	<0.0001
Boyfriend/girlfriend	31% (14603/46873)	35% (3279/9322)	<0.0001	43% (23289/54306)	48% (2993/6248)	<0.0001
Occasional/casual partner	0.85% (398/46873)	1.8% (168/9322)	<0.0001	6.6% (3588/54306)	9.9% (620/6248)	<0.0001
Other	0.90% (422/46873)	1.1% (99/9322)	0.153	2.0% (1069/54306)	2.1% (132/6248)	0.468
Missing	0.096% (45/46873)	0.18% (17/9322)	0.0338	0.18% (97/54306)	0.18% (11/6248)	0.999
Median length of relationship in years (IQR)	6.0 (3.0, 13)	1.0 (0.82, 4.0)	<0.0001	2.0 (0.66, 8.0)	1.0 (0.49, 4.0)	<0.0001
Relationship ongoing						
Yes	84% (39463/46873)	80% (7433/9322)	<0.0001	71% (38339/54306)	62% (3903/6248)	<0.0001
No	14% (6716/46873)	19% (1738/9322)	<0.0001	24%(13199/54306)	32% (2020/6248)	<0.0001
Don't know	1.1% (495/46873)	0.34% (32/9322)	<0.0001	0.30% (161/54306)	0.16% (10/6248)	0.0721
Missing	0.42% (199/46873)	1.3% (119/9322)	<0.0001	4.8% (2607/54306)	5.0% (315/6248)	0.418
Partner's residence						
Same household	67% (28257/41989)	65% (5291/8130)	0.000107	49% (23774/48330)	46% (2476/5439)	<0.0001
Same community, different household	13% (5551/41989)	11% (922/8130)	<0.0001	25% (12313/48330)	25% (1357/5439)	0.406
Outside community	19% (8137/41989)	23% (1895/8130)	<0.0001	25% (12186/48330)	29% (1600/5439)	<0.0001
Missing	0.10% (44/41989)	0.27% (22/8130)	0.000310	0.12% (57/48330)	0.11% (6/5439)	0.999
Partner's circumsision status						
Circumsised	36% (10102/27703)	43% (2143/4991)	<0.0001			
Uncircumsised	63% (17362/27703)	56% (2773/4991)	<0.0001			
Don't know	0.75% (207/27703)	1.2% (61/4991)	0.000836			
Missing	0.12% (32/27703)	0.28% (14/4991)	0.00787			

Condom usage with partner						
Never	68% (25158/37013)	63% (4768/7559)	<0.0001	54% (23102/42826)	56% (2794/4956)	0.00120
Inconsistent	20% (7428/37013)	26% (1929/7559)	<0.0001	21% (8851/42826)	20% (1006/4956)	0.556
Always	12% (4405/37013)	11% (846/7559)	0.0848	25% (10760/42826)	23% (1140/4956)	0.00114
Don't know	<0.01% (2/37013)	0.0% (0/7559)	0.999	<0.01% (4/42826)	0.020% (1/4956)	0.999
Missing	0.054% (20/37013)	0.21% (16/7559)	<0.0001	0.25% (109/42826)	0.30% (15/4956)	0.629
RCCS participant uses alcohol before sex with partner						
Yes	21% (1984/9310)	23% (585/2568)	0.115	34% (3837/11371)	31% (551/1792)	0.0134
No	79% (7326/9310)	77% (1971/2568)	0.0375	66% (7526/11371)	69% (1230/1792)	0.0436
Missing	0.0% (0/9310)	0.47% (12/2568)	<0.0001	0.070% (8/11371)	0.61% (11/1792)	<0.0001
Partner uses alcohol before sex with RCCS participant						
Yes	40% (3760/9310)	38% (973/2568)	0.0235	19% (2130/11371)	20% (359/1792)	0.202
No	60% (5549/9310)	62% (1583/2568)	0.0648	81% (9233/11371)	79% (1422/1792)	0.0693
Missing	0.011% (1/9310)	0.47% (12/2568)	<0.0001	0.070% (8/11371)	0.61% (11/1792)	<0.0001
Partner's HIV status was ever known by RCCS participant						
Yes	63% (11092/17660)	59% (2590/4382)	<0.0001	55% (11541/21034)	49% (1495/3035)	<0.0001
No	37% (6558/17660)	40% (1773/4382)	<0.0001	45% (9478/21034)	50% (1529/3035)	<0.0001
Missing	0.040% (7/17660)	0.43% (19/4382)	<0.0001	0.071% (15/21034)	0.36% (11/3035)	<0.0001
RCCS participant informed partner of his/her HIV status						
Yes	49% (8600/17660)	46% (2032/4382)	0.00612	39% (8285/21034)	33% (1014/3035)	<0.0001
No	16% (2774/17660)	17% (733/4382)	0.103	27% (5750/21034)	25% (772/3035)	0.0293
Never tested/got HIV results	5.7% (1011/17660)	12% (521/4382)	<0.0001	12% (2478/21034)	25% (765/3035)	<0.0001
Received couple counseling	30% (5270/17660)	25% (1080/4382)	<0.0001	21% (4507/21034)	16% (472/3035)	<0.0001
Don't remember	<0.01% (1/17660)	0.0% (0/4382)	0.999	<0.01% (1/21034)	0.0% (0/3035)	0.999
Missing	0.023% (4/17660)	0.37% (16/4382)	<0.0001	0.062% (13/21034)	0.40% (12/3035)	<0.0001

Data are % (n/N). Some percentages do not add up to 100 because of rounding.

Table 2: Characteristics of self-reported partners and partnerships of HIV-negative RCCS participants, 1996-2016

	Self-reported Male Partners (n=46839)			Self-reported Female Partners (n=53294)		
	Reported by Resident Females (n=39391)	**Reported by In-Migrant Females (n=7448)**	**P-value**	**Reported by Resident Males (n=47803)**	**Reported by In-Migrant Males (n=5491)**	**P-value**
Median partner age (IQR)	32 (26, 40)	27 (23, 33)	<0.0001	23 (19, 29)	22 (19, 27)	<0.0001
Partner age category						
15-19	3.8% (1200/31664)	4.4% (236/5398)	0.0444	24% (8982/37745)	25% (973/3868)	0.0620
20-24	11% (3578/31664)	23% (1264/5398)	<0.0001	27% (10013/37745)	32% (1228/3868)	<0.0001
25-29	17% (5246/31664)	24% (1274/5398)	<0.0001	19% (6990/37745)	18% (690/3868)	0.309
30-34	17% (5306/31664)	15% (808/5398)	0.00114	11% (4243/37745)	8.0% (310/3868)	<0.0001
35-39	13% (4113/31664)	8.2% (443/5398)	<0.0001	6.2% (2353/37745)	3.7% (145/3868)	<0.0001
40 or older	23% (7159/31664)	8.6% (463/5398)	<0.0001	3.7% (1390/37745)	2.3% (89/3868)	<0.0001
Don't know	15% (4894/31664)	15% (829/5398)	0.869	3.9% (1469/37745)	4.3% (167/3868)	0.210
Missing	0.53% (168/31664)	1.5% (81/5398)	<0.0001	6.1% (2305/37745)	6.9% (266/3868)	0.0629
Median age difference between partner and RCCS participant (IQR)	4.0 (2.0, 7.0)	4.0 (2.0, 7.0)	0.291	-4.0 (-7.0, -2.0)	-3.0 (-6.0, -1.0)	<0.0001
Partner age compared to RCCS participant's age						
Younger	3.6% (1143/31664)	3.3% (178/5398)	0.270	76% (28655/37745)	71% (2764/3868)	<0.0001
Same age	6.0% (1910/31664)	6.4% (348/5398)	0.252	8.6% (3243/37745)	9.8% (379/3868)	0.0122
Older by less than 5 years	37% (11822/31664)	36% (1942/5398)	0.0581	4.6% (1742/37745)	6.4% (246/3868)	<0.0001
Older by 5 to less than 10 years	23% (7417/31664)	24% (1318/5398)	0.116	0.69% (262/37745)	0.75% (29/3868)	0.769
Older by 10 or more years	14% (4310/31664)	13% (702/5398)	0.237	0.18% (69/37745)	0.44% (17/3868)	0.00157
Don't know	15% (4894/31664)	15% (829/5398)	0.869	3.9% (1469/37745)	4.3% (167/3868)	0.210
Missing	0.53% (168/31664)	1.5% (81/5398)	<0.0001	6.1% (2305/37745)	6.9% (266/3868)	0.0629
Partner's primary occupation						
Agricultural work	26% (10423/39391)	19% (1427/7448)	<0.0001	34% (16242/47803)	22% (1159/5491)	<0.0001
Housework	0.16% (62/39391)	0.23% (17/7448)	0.225	15% (7281/47803)	21% (1142/5491)	<0.0001
Bar or restaurant work	0.41% (161/39391)	0.38% (28/7448)	0.757	2.0% (958/47803)	3.6% (182/5491)	<0.0001
Government, clerical, or teaching work	9.8% (3853/39391)	10% (761/7448)	0.256	4.0% (1927/47803)	5.0% (298/5491)	<0.0001
Student	2.5% (987/39391)	2.0% (149/7448)	0.0105	14% (6492/47803)	12% (758/5491)	0.662
Shopkeeper	5.9% (2315/39391)	5.3% (394/7448)	0.0497	4.6% (2206/47803)	5.3% (292/5491)	0.0214
Trader or vender	21% (8263/39391)	18% (1357/7448)	<0.0001	3.2% (1535/47803)	4.6% (229/5491)	0.000196
Trucker	4.2% (1641/39391)	4.9% (367/7448)	0.00324	0.0% (0/47803)	0.0% (0/5491)	<0.0001
Hair dresser or salon owner	0.35% (137/39391)	0.68% (51/7448)	<0.0001	1.8% (872/47803)	3.0% (174/5491)	<0.0001
Construction	3.6% (1428/39391)	4.3% (323/7448)	0.00333	0.0% (0/47803)	0.016% (1/5491)	0.192
Other	22% (8746/39391)	27% (1980/7448)	<0.0001	5.0% (2400/47803)	6.6% (350/5491)	<0.0001
Unemployed	0.10% (38/39391)	0.054% (4/7448)	0.358	<0.01% (1/47803)	0.0% (0/5491)	0.999
Don't know	0.32% (125/39391)	0.38% (28/7448)	0.483	0.23% (110/47803)	0.37% (16/5491)	0.460
Missing	3.1% (1212/39391)	7.5% (562/7448)	<0.0001	16% (7779/47803)	17% (890/5491)	0.917
Relationship type						
Current husband/wife	45% (17698/39391)	25% (1887/7448)	<0.0001	29% (13963/47803)	18% (971/5491)	<0.0001
Current cohabitating partner (non-marital)	25% (9672/39391)	39% (2902/7448)	<0.0001	18% (8613/47803)	21% (1161/5491)	<0.0001
Boyfriend/girlfriend	29% (11274/39391)	33% (2453/7448)	<0.0001	44% (20945/47803)	49% (2674/5491)	<0.0001
Occasional/casual partner	0.87% (343/39391)	1.6% (120/7448)	<0.0001	6.8% (3256/47803)	10% (562/5491)	<0.0001
Other	0.92% (361/39391)	0.93% (69/7448)	0.987	2.0% (941/47803)	2.1% (116/5491)	0.500
Missing	0.11% (43/39391)	0.23% (17/7448)	0.0140	0.18% (85/47803)	0.13% (7/5491)	0.497
Median length of relationship in years (IQR)	6.0 (3.0, 13)	2.0 (0.82, 4.0)	<0.0001	2.0 (0.66, 8.0)	1.0 (0.49, 4.0)	<0.0001
Relationship ongoing						
Yes	86% (33780/39391)	81% (6041/7448)	<0.0001	70% (33658/47803)	62% (3413/5491)	<0.0001
No	13% (5032/39391)	17% (1298/7448)	<0.0001	25%(11727/47803)	33% (1806/5491)	<0.0001
Don't know	1.1% (419/39391)	0.26% (19/7448)	<0.0001	0.27% (131/47803)	0.15% (8/5491)	0.104
Missing	0.41% (160/39391)	1.2% (90/7448)	<0.0001	4.8% (2287/47803)	4.8% (264/5491)	0.965
Partner's residence						
Same household	70% (24649/35353)	67% (4372/6494)	0.000123	48% (20442/42484)	45% (2133/5439)	<0.0001
Same community, different household	12% (4395/35353)	10% (681/6494)	<0.0001	26% (11193/42484)	25% (1213/5439)	0.214
Outside community	18% (6270/35353)	22% (1421/6494)	<0.0001	25% (10797/42484)	30% (1406/5439)	<0.0001
Missing	0.11% (39/35353)	0.31% (20/6494)	0.000198	0.12% (52/42484)	0.11% (5/5439)	0.916
Partner's circumsision status						
Circumsised	36% (8379/23363)	42% (1672/3983)	<0.0001			
Uncircumsised	63% (14778/23363)	56% (2250/3983)	<0.0001			
Don't know	0.74% (174/23363)	1.3% (51/3983)	0.000767			
Missing	0.14% (32/23363)	0.25% (10/3983)	0.138			

Condom usage with partner						
Never	71% (22033/31090)	65% (3915/6033)	<0.0001	55% (20597/37659)	56% (2445/4376)	0.142
Inconsistent	19% (5774/31090)	25% (1504/6033)	<0.0001	20% (7578/37659)	20% (889/4376)	0.779
Always	10% (3261/31090)	10% (598/6033)	0.187	25% (9394/37659)	24% (1030/4376)	0.0432
Don't know	<0.01% (2/31090)	0.0% (0/6033)	0.999	0.011% (4/37659)	0.023% (1/4376)	0.999
Missing	0.064% (20/31090)	0.27% (16/6033)	<0.0001	0.23% (86/37659)	0.25% (11/4376)	0.894
RCCS participant uses alcohol before sex with partner						
Yes	20% (1549/7727)	20% (410/2050)	0.987	32% (3204/10058)	28% (458/1623)	0.00372
No	80% (6178/7727)	79% (1628/2050)	0.610	68% (6846/10058)	71% (1158/1623)	0.00893
Missing	0.0% (0/7727)	0.59% (12/2050)	<0.0001	0.080% (8/10058)	0.43% (7/1623)	0.000972
Partner uses alcohol before sex with RCCS participant						
Yes	39% (2987/7727)	35% (723/2050)	0.00535	17% (1731/10058)	18% (290/1623)	0.539
No	61% (4739/7727)	64% (1315/2050)	0.0210	83% (8319/10058)	82% (1326/1623)	0.337
Missing	0.013% (1/7727)	0.59% (12/2050)	<0.0001	0.080% (8/10058)	0.43% (7/1623)	0.000972
Partner's HIV status was ever known by RCCS participant						
Yes	65% (9515/14687)	63% (2207/3486)	0.106	56% (10235/18435)	51% (1390/2707)	<0.0001
No	35% (5167/14687)	36% (1260/3486)	0.294	44% (8185/18435)	48% (1310/2707)	0.000104
Missing	0.034% (5/14687)	0.55% (19/3486)	<0.0001	0.081% (15/18435)	0.26% (7/2707)	0.0187
RCCS participant informed partner of his/her HIV status						
Yes	49% (7230/14687)	48% (1684/3486)	0.338	40% (7360/18435)	34% (928/2707)	<0.0001
No	13% (1880/14687)	12% (414/3486)	0.147	26% (4825/18435)	25% (680/2707)	0.253
Never tested/got HIV results	5.8% (853/14687)	11% (382/3486)	<0.0001	12% (2246/18435)	24% (644/2707)	<0.0001
Received couple counseling	32% (4719/14687)	28% (990/3486)	<0.0001	22% (3990/18435)	17% (447/2707)	<0.0001
Don't remember	<0.01% (1/14687)	0.0% (0/3486)	0.999	<0.01% (1/18435)	0.0% (0/2707)	0.999
Missing	0.027% (4/14687)	0.46% (16/3486)	<0.0001	0.071% (13/18435)	0.30% (8/2707)	0.00167

Data are % (n/N). Some percentages do not add up to 100 because of rounding.

Table 3: Characteristics of self-reported partners and partnerships of HIV-positive RCCS participants, 1996-2016

	Self-reported Male Partners (n=9356)			Self-reported Female Partners (n=7260)		
	Reported by Resident Females (n=7482)	**Reported by In-Migrant Females (n=1874)**	**P-value**	**Reported by Resident Males (n=6503)**	**Reported by In-Migrant Males (n=757)**	**P-value**
Median partner age (IQR)	36 (30, 42)	30 (26, 37)	<0.0001	27 (23, 33)	26 (22, 30)	<0.0001
Partner age category						
15-19	5.3% (31/5899)	1.3% (17/1356)	0.00516	5.9% (308/5190)	8.8% (52/588)	0.00745
20-24	4.5% (263/5899)	12% (165/1356)	<0.0001	22% (1126/5190)	28% (163/588)	0.00106
25-29	13% (754/5899)	19% (262/1356)	<0.0001	27% (1378/5190)	25% (147/588)	0.448
30-34	18% (1054/5899)	18% (243/1356)	0.995	18% (911/5190)	14% (81/588)	0.0248
35-39	18% (1090/5899)	12% (159/1356)	<0.0001	10% (540/5190)	6.1% (36/588)	0.00132
40 or older	27% (1606/5899)	14% (196/1356)	<0.0001	6.4% (331/5190)	5.1% (30/588)	0.262
Don't know	18% (1059/5899)	21% (284/1356)	0.0118	5.2% (272/5190)	5.3% (31/588)	0.999
Missing	0.71% (42/5899)	2.2% (30/1356)	<0.0001	6.2% (324/5190)	8.2% (48/588)	0.0873
Median age difference between partner and RCCS participant (IQR)	4.0 (2.0, 7.0)	4.0 (2.0, 8.0)	0.0710	-5.0 (-8.0, -2.0)	-4.0 (-8.0, -2.0)	0.113
Partner age compared to RCCS participant's age						
Younger	7.5% (441/5899)	6.9% (94/1356)	0.527	76% (3945/5190)	71% (420/588)	0.0164
Same age	8.2% (485/5899)	7.2% (97/1356)	0.211	5.7% (295/5190)	8.3% (49/588)	0.0131
Older by less than 5 years	32% (1866/5899)	28% (381/1356)	0.0122	5.2% (272/5190)	5.3% (31/588)	0.999
Older by 5 to less than 10 years	19% (1120/5899)	19% (253/1356)	0.810	1.2% (61/5190)	0.85% (5/588)	0.618
Older by 10 or more years	15% (886/5899)	16% (217/1356)	0.386	0.40% (21/5190)	0.68% (4/588)	0.526
Don't know	18% (1059/5899)	21% (284/1356)	0.0118	5.2% (272/5190)	5.3% (31/588)	0.999
Missing	0.71% (42/5899)	2.2% (30/1356)	<0.0001	6.2% (324/5190)	8.2% (48/588)	0.0873
Partner's primary occupation						
Agricultural work	26% (1911/7482)	20% (378/1874)	<0.0001	40% (2615/6503)	29% (219/757)	<0.0001
Housework	0.15% (11/7482)	0.43% (8/1874)	0.0340	16% (1035/6503)	18% (139/757)	0.0934
Bar or restaurant work	0.76% (57/7482)	0.48% (9/1874)	0.251	4.2% (271/6503)	5.7% (43/757)	0.0654
Government, clerical, or teaching work	7.9% (591/7482)	7.5% (141/1874)	0.622	2.8% (182/6503)	1.8% (14/757)	0.160
Student	0.37% (28/7482)	0.37% (7/1874)	0.999	2.1% (135/6503)	2.8% (21/757)	0.262
Shopkeeper	4.6% (341/7482)	3.9% (73/1874)	0.237	4.2% (273/6503)	4.9% (37/757)	0.428
Trader or vender	21% (1564/7482)	19% (353/1874)	0.0511	5.6% (361/6503)	7.4% (56/757)	0.0473
Trucker	5.8% (431/7482)	5.5% (103/1874)	0.700	0.0% (0/6503)	0.0% (0/757)	0.999
Hair dresser or salon owner	0.32% (24/7482)	0.91% (17/1874)	0.00119	1.5% (96/6503)	1.8% (14/757)	0.523
Construction	4.0% (300/7482)	4.2% (79/1874)	0.735	0.0% (0/6503)	0.016% (1/757)	<0.0001
Other	24% (1819/7482)	25% (464/1874)	0.709	6.0% (389/6503)	8.1% (61/757)	0.0306
Unemployed	0.094% (7/7482)	0.053% (1/1874)	0.928	0.0% (0/6503)	0.0% (0/757)	0.999
Don't know	0.39% (29/7482)	0.80% (15/1874)	0.0318	0.34% (22/6503)	0.92% (7/757)	0.0343
Missing	4.9% (369/7482)	12% (226/1874)	<0.0001	17% (1124/6503)	19% (146/757)	0.186
Relationship type						
Current husband/wife	28% (2111/7482)	15% (279/1874)	<0.0001	30% (1939/6503)	18% (147/757)	<0.0001
Current cohabitating partner (non-marital)	26% (1924/7482)	37% (691/1874)	<0.0001	27% (1748/6503)	21% (213/757)	0.488
Boyfriend/girlfriend	44% (3329/7482)	44% (826/1874)	0.765	36% (2344/6503)	49% (319/757)	0.00114
Occasional/casual partner	0.74% (55/7482)	2.6% (48/1874)	<0.0001	5.1% (332/6503)	10% (58/757)	0.00414
Other	0.82% (61/7482)	1.6% (30/1874)	0.00301	2.0% (128/6503)	2.1% (16/757)	0.894
Missing	0.027% (2/7482)	0.0% (0/1874)	0.999	0.18% (12/6503)	0.13% (4/757)	0.134
Median length of relationship in years (IQR)	5.0 (2.0, 10)	1.0 (0.74, 4.0)	<0.0001	3.0 (0.90, 8.0)	2.0 (0.57, 5.0)	<0.0001
Relationship ongoing						
Yes	76% (5683/7482)	74% (1392/1874)	0.139	72% (4681/6503)	65% (490/757)	<0.0001
No	23% (1684/7482)	23% (440/1874)	0.386	23%(1472/6503)	28% (214/757)	0.000606
Don't know	1.0% (76/7482)	0.69% (13/1874)	0.250	0.46% (30/6503)	0.26% (2/757)	0.628
Missing	0.52% (39/7482)	1.5% (29/1874)	<0.0001	4.9% (320/6503)	6.7% (51/757)	0.0393
Partner's residence						
Same household	54% (3608/6636)	56% (919/1636)	0.199	57% (3332/5846)	50% (343/682)	0.000971
Same community, different household	17% (1156/6636)	15% (241/1636)	0.0104	19% (1120/5846)	21% (144/682)	0.241
Outside community	28% (1867/6636)	29% (474/1636)	0.520	24% (1389/5846)	28% (194/682)	0.00794
Missing	0.075% (5/6636)	0.12% (2/1636)	0.913	0.086% (5/5846)	0.15% (1/682)	0.999
Partner's circumsision status						
Circumsised	40% (1723/4340)	47% (471/1008)	<0.0001			
Uncircumsised	60% (2584/4340)	52% (523/1008)	<0.0001			
Don't know	0.76% (33/4340)	0.99% (10/1008)	0.585			
Missing	0.0% (0/4340)	0.40% (4/1008)	0.000445			

Condom usage with partner						
Never	53% (3125/5923)	56% (853/1526)	0.0306	48% (2505/5167)	60% (349/580)	<0.0001
Inconsistent	28% (1654/5923)	28% (425/1526)	0.979	25% (1273/5167)	20% (117/580)	0.0198
Always	19% (1144/5923)	16% (248/1526)	0.00693	26% (1366/5167)	19% (110/580)	0.000116
Missing	0.0% (0/5923)	0.0% (0/1526)	0.999	0.45% (23/5167)	0.69% (4/580)	0.620
RCCS participant uses alcohol before sex with partner						
Yes	27% (435/1583)	34% (175/518)	0.00719	48% (633/1313)	55% (93/169)	0.112
No	73% (1148/1583)	66% (343/518)	0.00719	52% (680/1313)	43% (72/169)	0.0303
Missing	0.0% (0/1583)	0.0% (0/518)	0.999	0.0% (0/1313)	2.4% (4/169)	<0.0001
Partner uses alcohol before sex with RCCS participant						
Yes	49% (773/1583)	48% (250/518)	0.862	30% (399/1313)	41% (69/169)	0.00781
No	51% (810/1583)	52% (268/518)	0.862	70% (914/1313)	57% (96/169)	0.00105
Missing	0.0% (0/1583)	0.0% (0/518)	0.999	0.0% (0/1313)	2.4% (4/169)	<0.0001
Partner's HIV status was ever known by RCCS participant						
Yes	53% (1580/2973)	43% (383/896)	<0.0001	50% (1306/2599)	32% (105/328)	<0.0001
No	47% (1391/2973)	57% (513/896)	<0.0001	50% (1293/2599)	67% (219/328)	<0.0001
Missing	0.067% (2/2973)	0.0% (0/896)	0.999	0.0% (0/2599)	1.2% (4/328)	0.999
RCCS participant informed partner of his/her HIV status						
Yes	46% (1370/2973)	39% (348/896)	0.000153	36% (925/2599)	26% (86/328)	0.000961
No	30% (894/2973)	36% (319/896)	0.00202	36% (925/2599)	28% (92/328)	0.00825
Never tested/got HIV results	5.3% (158/2973)	16% (139/896)	<0.0001	8.9% (232/2599)	37% (121/328)	<0.0001
Received couple counseling	19% (551/2973)	10% (90/896)	<0.0001	20% (517/2599)	7.6% (25/328)	<0.0001
Missing	0.0% (0/2973)	0.0% (0/896)	0.999	0.0% (0/2599)	1.2% (4/328)	<0.0001

Data are % (n/N). Some percentages do not add up to 100 because of rounding.

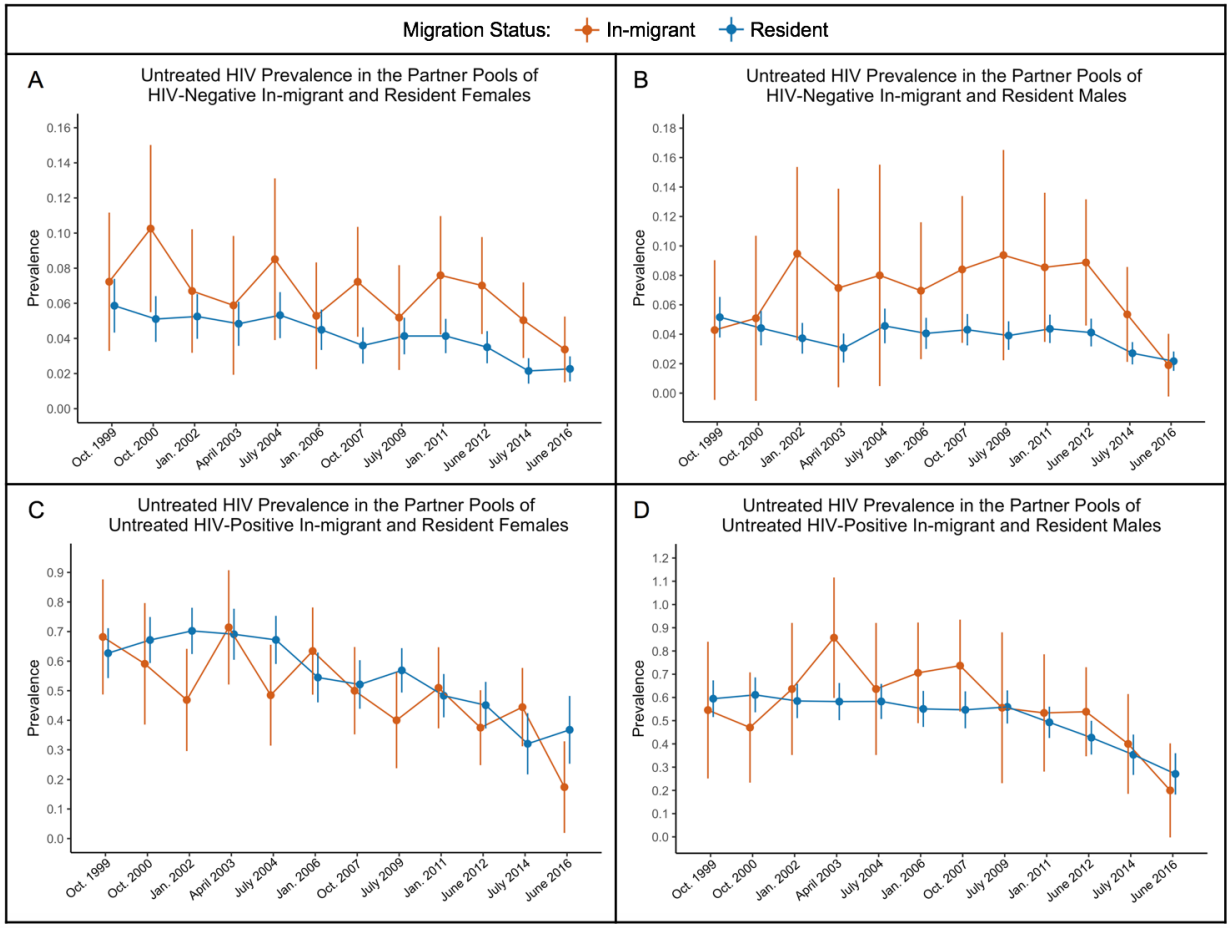


Figure 1. Prevalence of partnership with an untreated HIV-positive partner among HIV-negative females (Panel A), HIV-negative males (Panel B), untreated HIV-positive females (Panel C), and untreated HIV-positive males (Panel D) in the RCCS, 1999-2016. Prevalence is stratified by migration status (in-migrant or resident) of the reporting partner.

Table 4: Prevalence risk ratios comparing in-migrants to residents, stratified by gender

Outcome of Interest	Female PRR (95% CI)	Male PRR (95% CI)
Partnership with one or more untreated HIV-positive persons, among HIV-negative RCCS Participants		
All survey rounds	1.55 (1.30, 1.85)	1.74 (1.40, 2.17)
Pre-CHP	1.46 (1.12, 1.91)	1.63 (1.08, 2.46)
Early CHP	1.57 (1.19, 2.07)	1.91 (1.36, 2.70)
Late CHP	1.95 (1.43, 2.65)	1.81 (1.22, 2.68)
Survey round 12	1.49 (0.79, 2.82)	0.85 (0.27, 2.73)
Partnership with one or more untreated HIV-positive persons, among untreated HIV-positive RCCS participants		
All survey rounds	0.87 (0.78, 0.96)	1.06 (0.92, 1.21)
Pre-CHP	0.84 (0.72, 0.99)	1.04 (0.84, 1.29)
Early CHP	0.97 (0.83, 1.15)	1.21 (0.99, 1.47)
Late CHP	0.93 (0.72, 1.21)	1.10 (0.80, 1.53)
Survey round 12	0.47 (0.18, 1.22)	0.71 (0.25, 2.07)
Partnership with in-migrant		
All survey rounds	20.92 (18.56, 23.67)	7.28 (6.94, 7.64)
HIV-positive		
All survey rounds	1.30 (1.19, 1.41)	1.07 (0.93, 1.22)
On ART, among HIV-positive RCCS participants		
Early and late CHP	0.55 (0.44, 0.66)	0.47 (0.31, 0.66)
Early CHP	0.35 (0.19, 0.58)	0.52 (0.22, 0.97)
Late CHP	0.58 (0.47, 0.70)	0.42 (0.26, 0.62)

PRR = Prevalence Risk Ratio
CHP = Combination HIV Prevention

Supplementary Appendix

Supplementary Table 1: Survey rounds and corresponding calendar years during which characteristics of self-reported partners were collected in the RCCS

Variable	Survey Rounds	Calendar Years
Partner age	1-10	1999-2012
Age difference between partner and RCCS participant	1-10	1999-2012
Partner's primary occupation	1-12	1999-2016
Relationship type	1-12	1999-2016
Length of relationship	1-12	1999-2016
Relationship ongoing	1-12	1999-2016
Partner's residence	1-11	1999-2014
Male partner's circumcision status	4-10	2002-2012
Condom usage with partner	4-12	2002-2016
RCCS participant uses alcohol before sex with partner	11-12	2014-2016
Partner uses alcohol before sex with RCCS participant	11-12	2014-2016
Partner's HIV status was ever known by RCCS participant	9-12	2011-2016
RCCS participant informed partner of his/her HIV status	9-12	2011-2016

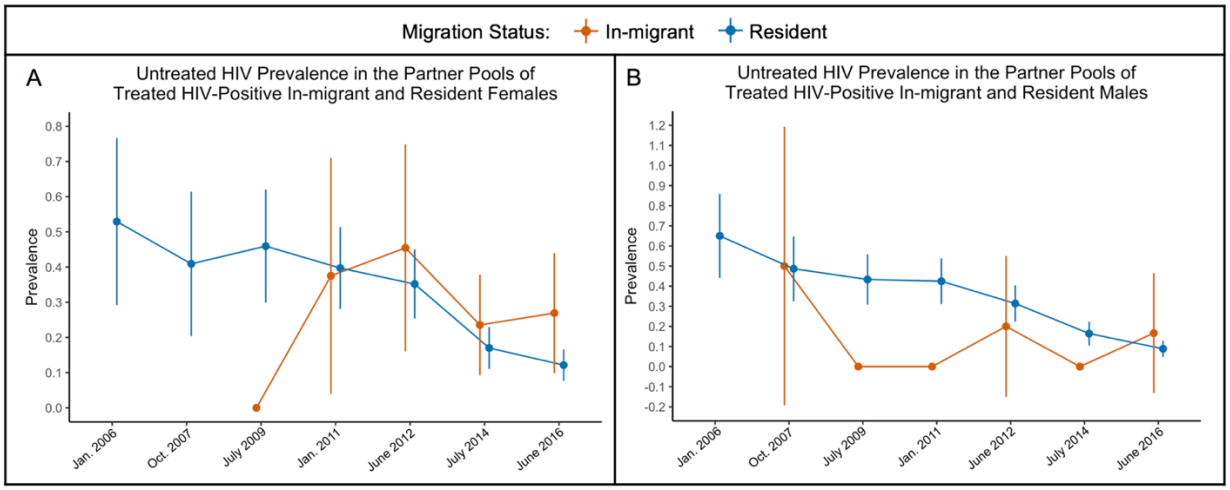
Supplementary Table 2: Time periods with corresponding survey rounds and calendar time in the RCCS

Time Period	Survey Round	Calendar Time
Pre-CHP	1	Oct. 1999
	2	Oct. 2000
	3	Jan. 2002
	4	April 2003
	5	July 2004
Early CHP	6	Jan. 2006
	7	Oct. 2007
	8	July 2009
	9	Jan. 2011
Late CHP	10	June 2012
	11	July 2014
	12	June 2016

Supplementary Table 3: Assortative mixing by migration status

	In-migrant Males	Resident Males
In-migrant Females	1162	2149
Resident Females	299	17530

Cells contain couple-visits.



Supplementary Figure 1. Prevalence of partnership with an untreated HIV-positive partner among treated HIV-positive females (Panel A) and treated HIV-positive males (Panel B) in the RCCS, 1999-2016. Prevalence is stratified by migration status (in-migrant or resident) of the reporting partner.

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Biography

Jennifer Brophy was born in 1993 in Bloomington, Indiana. She did her undergraduate studies at Emory University, where she majored in Biology and minored in Global Health. Jennifer completed her senior honors thesis research on *Streptococcus pneumoniae* biofilm strain interactions, population dynamics, and antibiotic resistance. She graduated *manga cum laude* in 2016.

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